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August 23, 1991

MEMORANDUM

FROM: Don H. Kampbell Don Kampbell
Subsurface Processes Branch

TO: Jon Josephs
Emergency & Remedial Response Branch
U.S. EPA, Region II
Jacob K. Javits Federal Building
New York, NY 10278

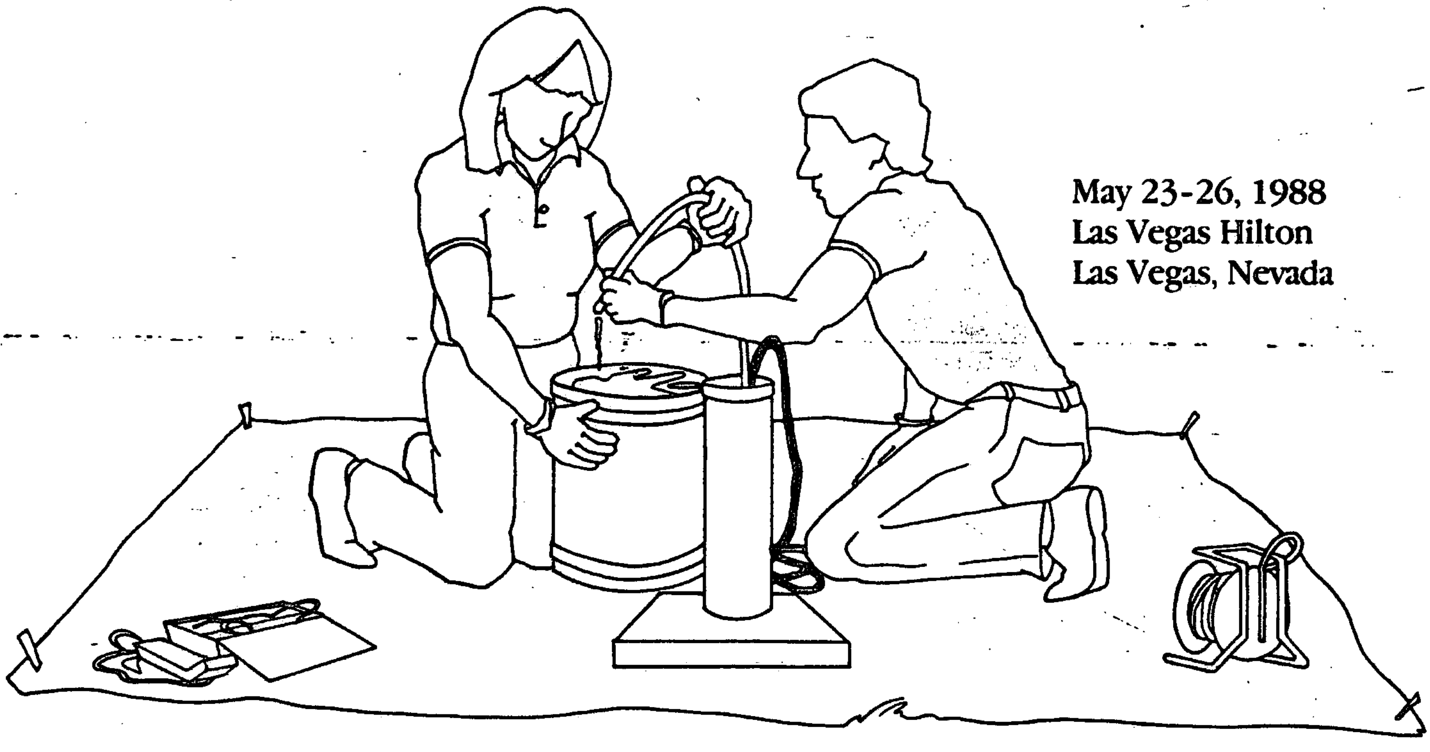
Enclosed is a publication that describes our field aseptic core sampling procedure. Once the core material is contained inside the tube sampler, extrude it into clean glass one-pint canning jars. This does not have to be done inside a nitrogen filled glovebox. Fill the jars with core material and quickly cap to minimize volatile losses. Record on each jar the date, drilling location, and increment of the profile. Sample the profile from the surface down to at least one foot below the water table. Store the filled jars at near the ground-water temperature. Avoid placing the filled jars in direct sunlight and at temperatures warmer than the ground water. Wrap each sample jar in foam sheeting or other suitable material and place into coolers for shipment by overnight air express to me.

Attachment

Proceedings of the

Second National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods

Volume I



May 23-26, 1988
Las Vegas Hilton
Las Vegas, Nevada

The follow-up conference to the highly acclaimed First National Outdoor Action Conference

The Association of Ground Water Scientists and Engineers is affiliated with the American Association for the Advancement of Science

Presented by the Association of Ground Water Scientists and Engineers & U.S. EPA EMSL - Las Vegas

ASEPTIC SUBSURFACE SAMPLING TECHNIQUES

FOR HOLLOW-STEM AUGER DRILLING

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ABSTRACT

Recent literature has described some inherent problems in the collection of in situ core samples in saturated materials with hollow-stem auger equipment, particularly in non-cohesive heaving sands or "sandblows." Collecting undisturbed uncontaminated subsurface materials and constructing monitoring wells for detecting low levels of statistically significant contaminants have become extremely important for monitoring RCRA and CERCLA sites, particularly for biological characterization.

Alterations of recently developed hollow-stem auger tools and the development of novel field sampling equipment has solved many of the problems of in situ profile sampling in non-cohesive heaving materials. A unique sampling tool, referred to as the "Waterloo Cohesionless-Aquifer Core Barrel," for sampling heaving saturated material has been redesigned so the internal vacuum piston can be used in the Central Mine and Equipment Company's 4-inch (10 cm) O.D. sample tube.

A clam-shell cap was fitted to the bottom of the hollow-stem auger bit replacing the standard center plug. This cap serves as a plug for the hollow auger while drilling to a desired sampling depth. Undisturbed samples are collected by lowering the sample tube into the hollow auger to the closed clam shell, retracting the auger about one foot--thereby opening the clam shell--and then driving the sample tube to the desired depth with a rig mounted percussion hammer. The redesigned internal piston inside the sample tube is held stationary by a wireline rigidly fixed to the rig. Holding the piston stationary while lowering the sampler creates a vacuum on the non-cohesive sample, holding it in the tube during retrieval from the borehole.

After retrieval, the piston is removed, the sampler is mounted in a hydraulic extruder, and samples are pressed from the tube through an attached paring device inside an aseptic glove box. The glove box is designed with a regulated nitrogen flow-through purging system and with a diaphragm port where the sampler can be inserted prior to sample extrusion.

INTRODUCTION

Hollow-stem augers have been used extensively as a practical method of borehole construction in unconsolidated material for monitoring wells, soils investigation, and other geotechnical work since the 1950's. The use of hollow-stem auger equipment has become even more popular during the 1980's as a result of the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) programs in which special attention is paid to the collection of samples and the construction of monitoring wells (Wilson 1986). At the present, hollow-stem auger drilling represents the most widely used drilling method involved in constructing monitoring wells and soil sampling (McCray 1986). It has been estimated that more than 90 percent of all monitoring wells installed in unconsolidated materials in North America are constructed using hollow-stem augers (Riggs and Hatheway 1986).

There have been a number of recent articles written on hollow-stem auger drilling procedures (Perry 1985, Hacket 1987, Keely 1987a, Hackett 1988, and Keely 1987b). Equipment developed by essentially all of the major drill rig manufacturers performs extremely well for monitoring well construction and soil sampling where the unconsolidated material contains sufficient clay to maintain minimum cohesive properties, even below the water table. However, the use of conventional hollow-stem auger equipment in heaving sediments continue to plaque well drillers during well construction and depth discreet sampling.

The new tools described in this article, one of which has been modified from equipment previously developed at the Institute of Groundwater Research at the University of Waterloo, Ontario, Canada (Zapico 1987), have dramatically enhanced the ability to collect samples with miniminal physical and environmental disturbance. Sampling normally should be conducted using traditional procedures with the hollow-stem auger equipment in the unsaturated zone and all saturated soils where heaving does not occur since samples can be obtained much faster than with the new tools detailed in this article. However, once the borehole has reached the saturated zone and heaving is encountered, continuous sampling normally can only be accomplished using a clam-shell cap fitted to the hollow-stem auger bit or with a bit fitted with a knock-out plug.

This equipment is required to keep unconsolidated material out of the auger until the sampling tool is in place. This article describes successful operating procedures for a modified piston type sampler designed similar to the "Waterloo Cohesionless-Aquifer Core Barrel."

In addition to the sample collection tools, a portable glove box has been developed for use in the field to collect samples from the core barrel as they are hydraulically extruded and pared during collection. The glove box is designed with a flow through nitrogen gas purging system so sample integrity of chemical and biological regimes are maintained.

TRADITIONAL WELL CONSTRUCTION TECHNIQUES WITH HOLLOW-STEM AUGER EQUIPMENT

Traditional hollow-stem auger techniques for well construction and soil sampling and their limitations are first discussed to serve as a comparison to innovative techniques presented in this paper.

The obvious advantage of using hollow-stem auger equipment is that well construction and subsurface sampling can be conducted without using drilling fluids, and thus the chemical and biological integrity of the subsurface is maintained or at least its disturbance is minimized. During normal drilling with hollow-stem augers, a pilot assembly is used to keep the annular area of the hollow-stem auger free of cuttings (Figure 1). This assembly is equipped with a cutting head that functions as a pilot bit and is coupled at the spindle of the drill rig along with the hollow-stem auger. Both drilling tools are axially rotated and vertically advanced at the same rotational speed (Central Mine Equipment Company, 1987, Mobile Drilling Company, 1983).

Other tools occassionally substituted for the pilot assembly are the reverse flight auger or non-retrievable knock-out plates (Figures 2 and 3). All three of these hollow-stem annular plugs work well for boreholes constructed in unconsolidated material containing sufficient clay that minimum cohesive properties exist. In such materials, wells can be constructed or sampling can be performed without the invasion of heaving material when the internal tools are removed. In such soil conditions, well construction is normally quite simple. The borehole walls in cohesive materials will generally stand open, both above and below the water table, long enough that drilling tools can be removed and the well screen and casing can be set in the open borehole. Gravel packing, sealing and cementing can be performed more easily in open hole conditions.

Where the subsurface material does not contain sufficient clay, the borehole walls will quickly collapse when the auger is removed, particularly below the water table, even if soil and hydraulic conditions are stable enough that heaving does not occur when the inner tools are removed. Well construction under these circumstances can best be accomplished by using the hollow-stem augers as a temporary casing according to the manufacturers intended purpose. The well screen and casing can be inserted into the annular space of the auger and gravel packed to the desired elevation as the auger is removed. Normally only 1 to 1.5 feet (30 to 45

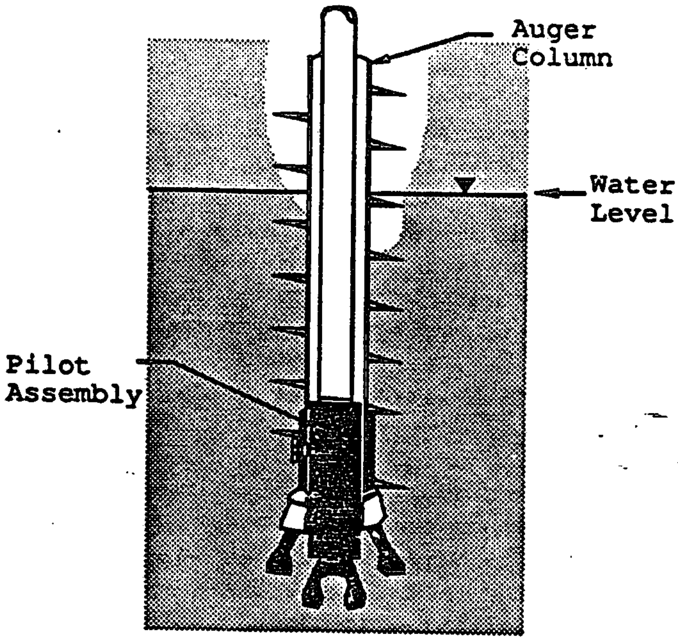

Figure 1. Borehole Advanced Into Saturated Sand with Auger Column Containing Pilot Assembly

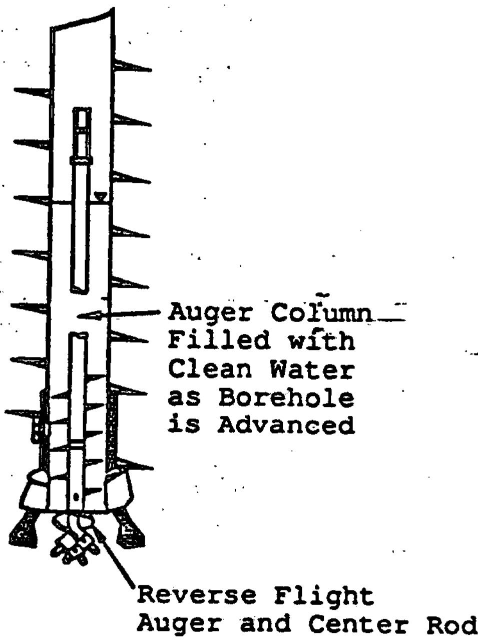

Figure 2. Borehole Construction Using a Reverse Flight Auger

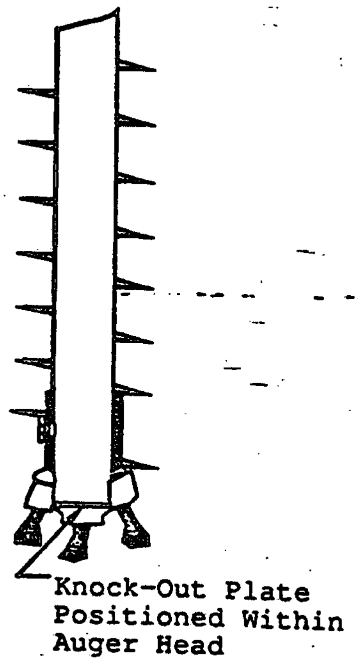

Figure 3. Borehole Construction Using a Knock-Out Plate

cm) of gravel pack material is added, the top of the casing is held rigid with the spindle or some immovable part of the drill rig, and the auger is slowly retracted, initially only about 1 to 1.5 feet (30 to 45 cm) to avoid bridging. This cycle is continually repeated until the gravel pack has been brought to the correct elevation. The elevation of the top of the gravel pack should be determined each time the auger is retracted to verify its correct elevation after slumping has occurred. A 1 to 2 foot (30 to 60 cm) bentonite seal can be placed above the gravel pack in the same manner and then the remainder of the borehole can be backfilled with soil, cuttings, or cement. Finally, the borehole should be cemented from below the frost line to the surface and the casing should be covered with a proper sanitary seal.

Well construction and soil sampling in loosely compacted non-cohesive saturated sands, known as "heaving sands" or "sandblows" have continually plagued well drillers and field engineers. The most common method used to control heaving problems has been to add fresh water inside the hollow-stem auger soon after the water table has been penetrated. Water is continually added with the pilot assembly left in position. The borehole generally is drilled to the desired depth in this manner so that the movement of sand and silt between the inside of the auger and the outside of the pilot assembly is minimized. This procedure also helps keep the head of the pilot assembly from sand-locking inside the hollow-stem auger. When wells are completed in this manner, one must realize that the integrity of the borehole, aquifer, and samples are all jeopardized. However, well screens can normally be set at the desired depth inside the hollow-stem augers using this procedure with minimal heaving occurring. Final well construction inside the hollow auger is conducted as described earlier.

Another reported drilling technique, to overcome the problem of heaving sands, has been to replace the traditional pilot assembly and center rod with a non-retrievable knock-out plate. This plate is wedged inside the auger head and plugs the annular area of the auger as it is advanced through heaving material. Once the desired depth is reached, the column is filled with fresh water to a height sufficient to exceed the hydrostatic pressure of the formation to prevent heaving sediments rising inside the auger column once the knock-out plate is removed. In many instances, the knock-out plate can be dislodged without flooding the column with water by using the well screen and casing as a ramrod. Normally a thin 2-3 inch (5 to 8 cm) gravel base is placed beneath the screen and 1-1.5 feet (30 to 45 cm) of gravel pack placed around the screen before the casing and screen are used as a ramrod to press the knock-out plate free of the auger head. The auger flights are lifted while vertical pressure is applied to the knock-out plate. The partial gravel pack helps to plug heaving material as well construction is completed inside the auger during its retrieval. The obvious disadvantages of this drilling technique are that the knock-out plate cannot be retrieved and if not constructed of inert materials, its oxidation in corrosive environments could impact specific sample parameters. In this option, a new plate would be required for each borehole. The supplemental use of a fresh water hydrostatic head may be equally undesirable (Barcelona 1986). In some specific cases, knock-out plates that are slotted or screened have been used to allow formation fluids to flood the interior of the auger as drilling progresses to the desired depth. This method has worked satisfactorily in coarse clean sands but the slots and screens tend to plug when drilling in silts and clays. These special knock-out plates can become prohibitively expensive if a very large number of wells is required.

DRILLING WITH A CLAM-SHELL CAPPED AUGER HEAD

An innovative clam-shell cap has been successfully used to replace the knock-out plate or pilot assembly for well construction and soil sampling in saturated heaving sands (Figure 4). This cap is mounted on hinges which are welded to the auger head and is held closed by vertical pressure as the auger is rotated and vertically advanced (Gillham 1982). It is essential that vertical pressure be continuously maintained to hold the flaps of the clam-shell closed until actual well construction begins inside the auger. With the clam-shell closed only minor leakage of formation fluids occur, thus if well screens and casing are set within a half-hour or so, the auger column will be relatively free of formation fluids.

Using the clam-shell device for well construction is quite similar to the knock-out plate except the auger column is not flooded with water, thus subsurface integrity is maintained. The principal application of this device is to construct wells and collect samples at any desired depth in saturated heaving sandy material where previous techniques have generally been unsuccessful. This apparatus adds no advantage to traditional techniques for either well construction or soil sampling where soils contain sufficient cohesive properties that heaving does not occur, however; the tool works equally well in cohesive soils.

After the borehole has been advanced to the desired depth in saturated sand, a 2-3 inch (5 to 8 cm) layer of gravel pack material is placed inside the hollow auger while the clam-shell remains in the closed position. The well screen and casing are then inserted inside the hollow auger and partially gravel packed. This partial packing serves to plug heaving materials from entering the hollow auger when the clam-shell is forced open by vertical pressure of the well screen and casing as the auger is initially raised 1 to 1.5 feet (30 to 45 cm). Well construction then proceeds as described previously using internal auger construction methods. Once the clam-shells are opened, it is absolutely essential that no rotation of the auger flighting occur or the clam-shells will be broken from their hinges and lost in the borehole. Care must be taken during retrieval of the auger once the clam-shells are open to avoid damage. Damage can be avoided if the auger holding fork is properly set in place.

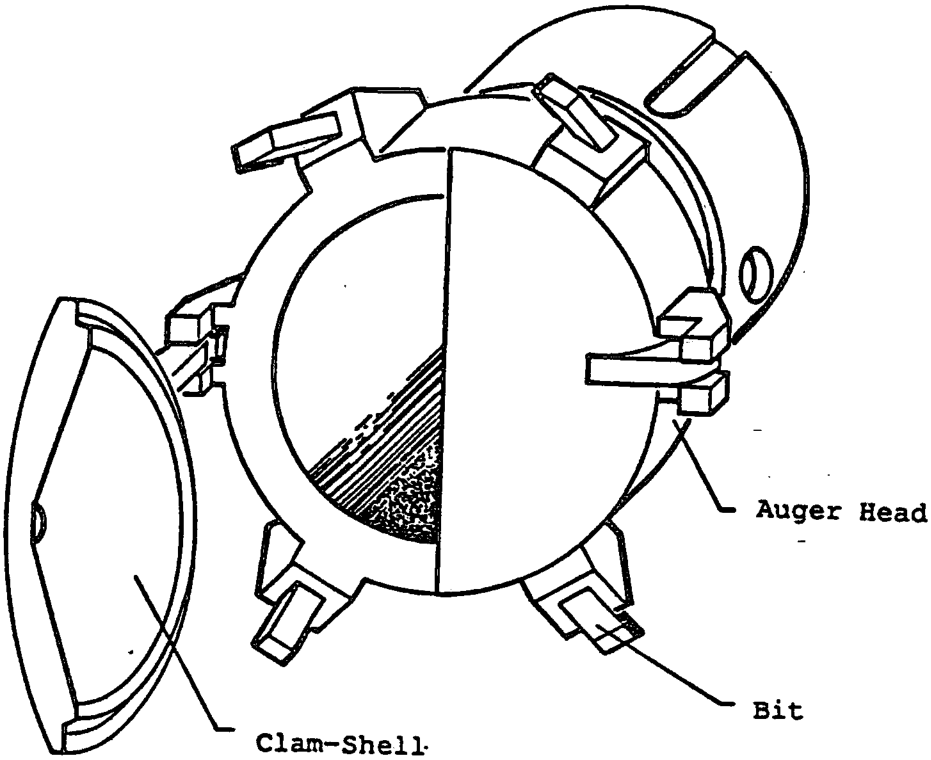

Figure 4. Clam-Shell Fitted Auger Head

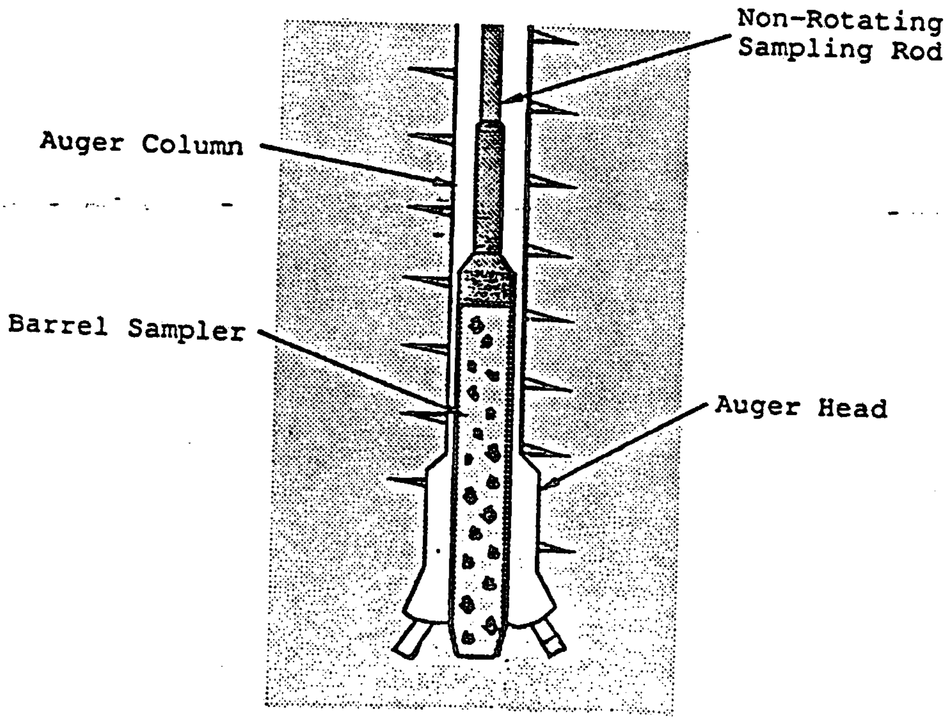

Figure 5. Diagram of Continuous Sampling Tube System
(After Central Mine Equipment Co. 1987)

The fork should be pushed firmly through the auger spiral and rotated clockwise to a tight position during each uncoupling. This will assure the augers will not fall during uncoupling and break the clam-shells from their hinges.

The obvious advantages of the use of this clam-shell device in lieu of traditional equipment in heaving sands are that: 1) no foreign objects are left in the borehole; 2) it is unnecessary to add water to develop a hydraulic pressure head; and 3) accurate positioning of the well screen and placement of a quality gravel pack and bentonite seal can be accomplished.

SOIL SAMPLING WITH CONVENTIONAL TOOLS AND THE "WATERLOO COHESIONLESS-AQUIFER CORE BARREL"

Traditional sampling of unconsolidated materials with a hollow-stem auger is managed by inserting a split spoon sampler or thin walled sampling tube inside the auger replacing the conventional rotating pilot assembly (Figure 5). Modifications are also made in the spendle assembly by adding an in-line bearing so that the center rod holding the sample tube is locked in a nonrotating position while the augers can continue to rotate for drilling (Central Mine and Equipment Company, 1987). This design allows the nonrotating sample tube or core barrel to be vertically advanced inside the rotating auger. Samples are thus collected with minimal disturbance. During advancement of the core barrel, the cutting shoe of the sampler pares the sample as it is pushed into the sample tube. Fluids and air trapped inside the tube above the sample are vented through a ball valve inside the drive head attached to the top of the sampler as it is forced into the soil.

For those rigs equipped with hydraulically or mechanically operated reciprocating percussion hammers, samples can be collected with either a split spoon sampler or a thin walled sampler (Figure 6). During collection of samples in this manner, the borehole is normally drilled to the desired depth with a hollow-stem auger with the internal pilot assembly in place. At the desired sample depth, the pilot assembly is removed, the sampler is inserted and then driven to the sampling depth. The sample tube and center rods are retrieved on a wireline or if necessary with the hydraulically operated spindle. Both the drilling and hammer sampling methods work well in materials which contain sufficient clay to retain cohesive bonding of soil particles. However, when saturated, totally cohesionless heaving sands are encountered, sampling is extremely difficult and often impossible with conventional tools and methods as described. Samples fall out of the sample tube during retrieval, even from tools with basket core retainers. Continuous difficulties of trying to collect samples of cohesionless sands and gravels led researchers at the Institute for Groundwater Research at the University of Waterloo, Ontario, Canada to develop their "Waterloo

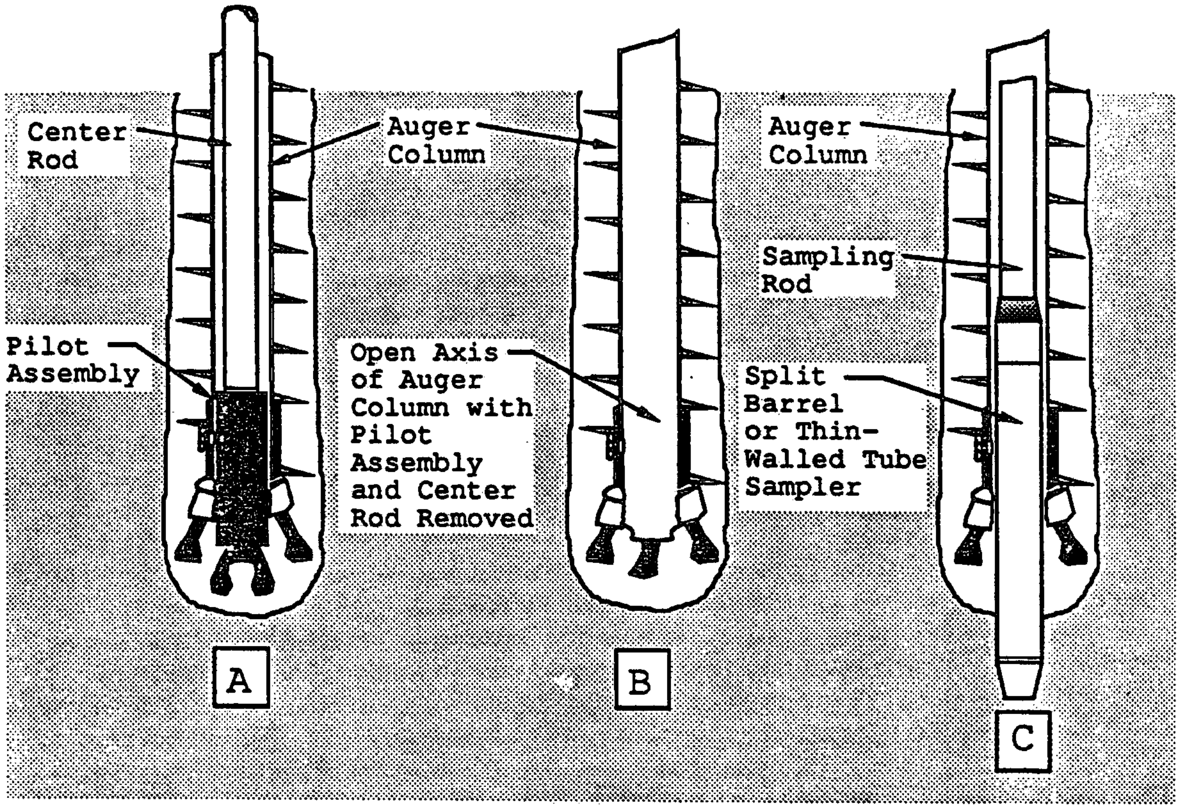

Figure 6. Sequential Steps Showing Borehole Advancement with Pilot Assembly and Collection of a Formation Sample (Riggs 1983)

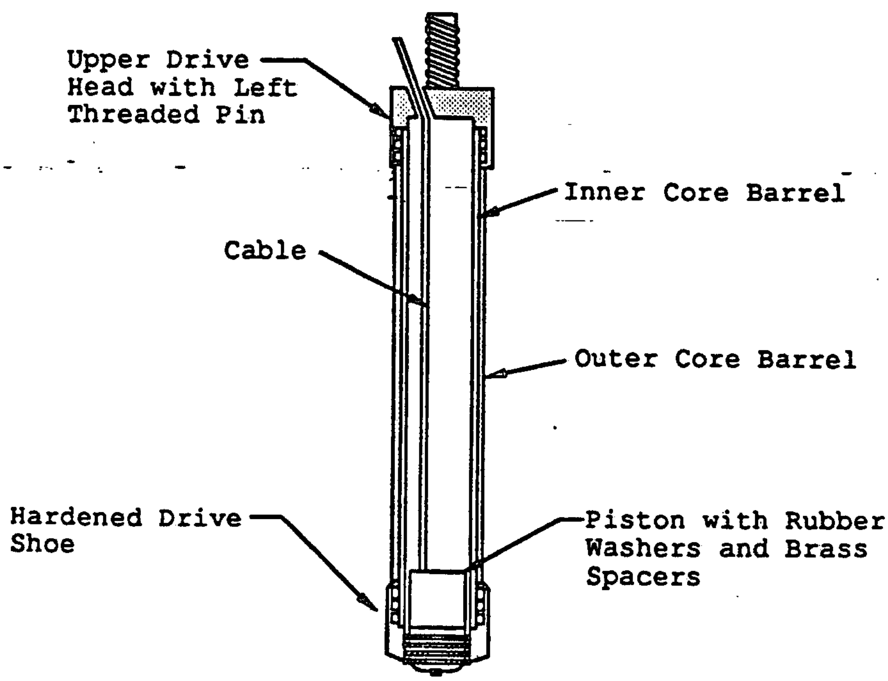

Figure 7. Waterloo Aquifer Piston Core Barrel-Schematic (Zapico 1987)

Cohesionless-Aquifer Core Barrel" (Figure 7). This innovative tool is effective for collecting non-cohesive sands. The core-barrel sampler is designed with an internal aluminum or plastic tube to collect undisturbed sediment and its original pore water, which offers advantages in studies of ground water chemistry or microbiology (Zapico 1987). The internal sample tube can be removed from the core barrel when raised to the surface. The tube can be opened in the field for subsampling or sealed and transported to a laboratory for later studies.

The sampler is designed with an internal piston attached to a wireline tautly fixed to the rig after the sample tube has been lowered to the sampling point. Sampling is done by percussion driving of the sampler downward by reciprocal pounding on the hammer-drive head (anvil) attached to the end of the center rod at the surface. As the sampler is driven the wireline holds the piston at its initial position creating a vacuum on the sample as it is collected and retrieved to the surface. The Waterloo sampler is also equipped with a left hand threaded drive head so that the center rod can be decoupled from the sampler before it is extracted from soil. The string of center rods are retrieved once they are decoupled and the sampler is then retrieved using the wireline connected to the piston. The designers contend this retrieving technique will minimize sample loss caused by the delay and the vibrations that accompany center rod hoisting and disconnection.

When using Waterloo's piston sampler, the annular column of the hollow-augers are normally flooded with drilling mud or freshwater to establish hydrostatic equilibrium of heaving aquifers. As noted earlier, this method of holding the borehole open for sampling is undesirable, particularly for researchers, since fluids or chemicals introduced into the borehole can grossly affect and pore water geochemistry and soil microorganisms. In addition, extensive field testing of the original "Waterloo Cohesionless-Aquifer Core Barrel" in extremely fluid non-cohesive coarse sands revealed problems of consistent sample collection. Occassionally the sampled material could not be retained during retrieval. Since cohesionless sands often require investigation during ground-water remediation research, improved methods of sample collection were sought.

ASEPTIC SAMPLING COMBINING INNOVATIVE FEATURES OF THE WATERLOO AND OTHER SAMPLERS

This paper describes modifications that have been made to Central Mine and Equipment Company's (CME) 4-inch (10 cm) I.D. by 5-foot (150 cm) long standard thin walled sampler to make it more functional for sampling cohesionless sands, particularly in heaving aquifer conditions. The major modifications involved combining features of the CME sampler and most features of the internal piston and attached wireline assembly used in the "Waterloo Cohesionless-Aquifer Core Barrel". It was essential to maintain the basic CME thread and dimensional designs so that all the standard CME tools would remain compatible with the CME hollow-stem auger drill used in collecting unconsolidated samples with many different lithologic properties, including heaving watery sands. The writers CME hollow-stem auger drill rig is equipped with a 5-foot (150 cm) hydraulically operated ram capable of extruding cores from the standard 4-inch (10 cm) I.D. by 5-foot (150 cm) long thin walled CME sample tube. Soil sample collection for ground-water research includes extruding and paring samples into serile containers in the field, therefore; Waterloo's inner aluminum or plastic soil collection sleeve liner was not included as part of the design modifications of the CME soil sampler.

The modified CME 4-inch (10 cm) I.D. sampler consists of the following original components: the upper sampler drive head containing left hand female threads with an internal pressure relief ball valve; the 5-foot (150 cm) thin wall sample tube threaded with left hand male threads on both ends; a core retainer basket and a hardened steel drive shoe with left hand female threads. CME's thread design prevents the traditional sample tube inadvertently being disassembled in the borehole by the rotating auger and binding soils in the annular area of the auger (Figure 8).

The standard CME thin walled sample tube was fitted with a wireline attached piston constructed similar to Waterloo's design (Figure 9). The redesign of the piston included modification of the compression design of the four neoprene washer seals and brass bushing assembly to include eight allen-head compression screws instead of one large compression nut. This modification allows a uniform compression adjustment of the neoprene seals to enhance the vacuum capabilities of the piston. The redesign also included a teflon wiper disk and stainless steel cap on the bottom of the piston to eliminate potential contamination of the sample which might occur as a result of organic decomposition of the neoprene washers.

Initially, a hardened steel drive shoe without a core catcher basket, designed like Waterloo's tool, was tested with a piston positioned flush with the cutting edge of the shoe. However, when tested in very fluid heaving sands, the piston would not consistently create sufficient suction to hold the cored sample in the tube when raised above the heaved material. Assembly with the original CME core catcher basket and cutting shoe was reverted to solve this problem, as described in the sampling procedures below. With this modification in collection technique, an excess of 90 percent core recovery has been possible.

The sampler drive head was modified with a 3/8-inch (1.0 cm) diameter hole through the top, just outside the drill rod connection, to allow the internal piston cable to pass through the drive head to the surface. CME's original ball valve design was retained so trapped air and water can be displaced as the piston is retracted during sampling. The ball valve also serves as a seal to keep ground water and soil particles from

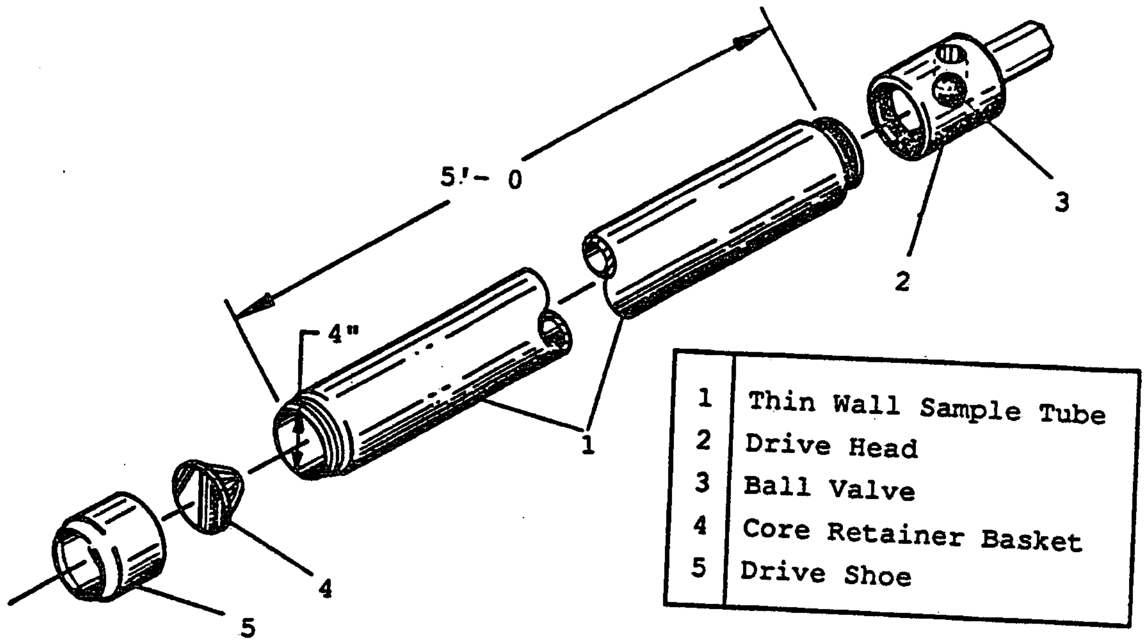

Figure 8. CME Standard Thin Wall Sample Tube

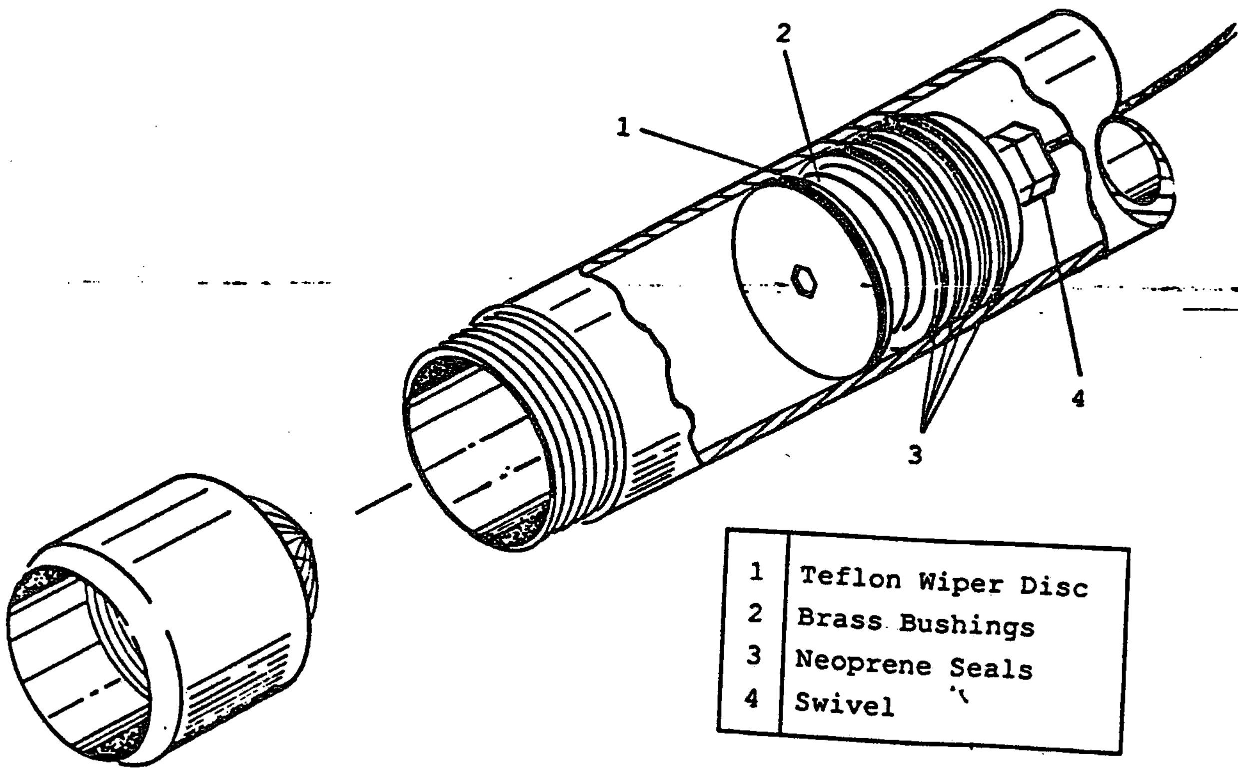

Figure 9. Modified Wireline Piston Design

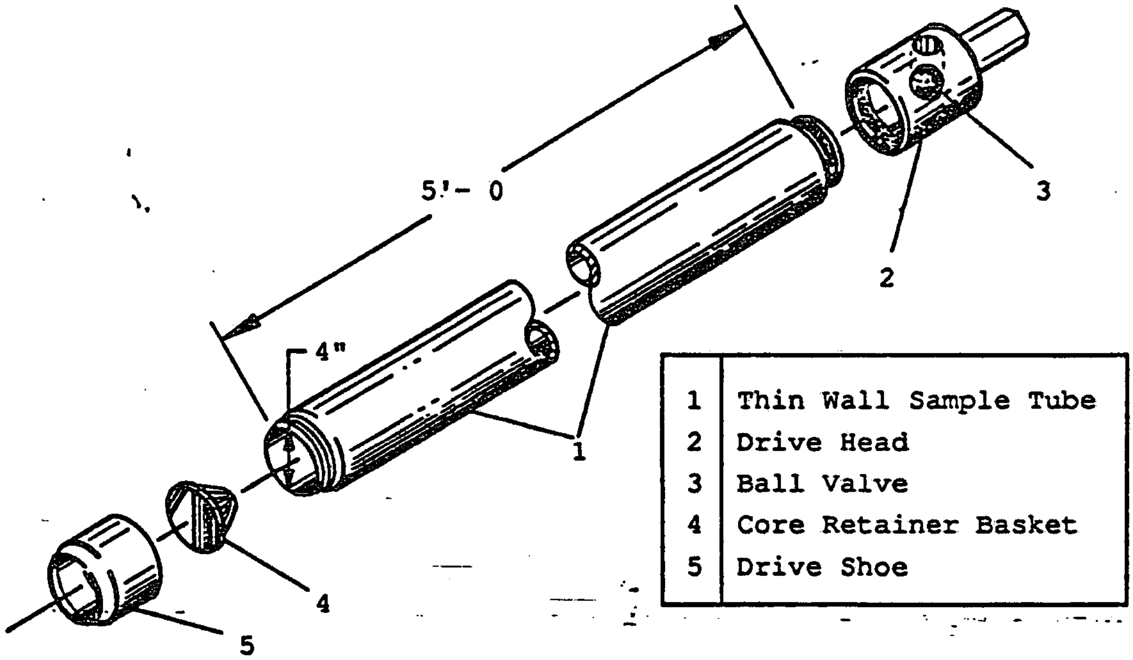

Figure 8. CME Standard Thin Wall Sample Tube

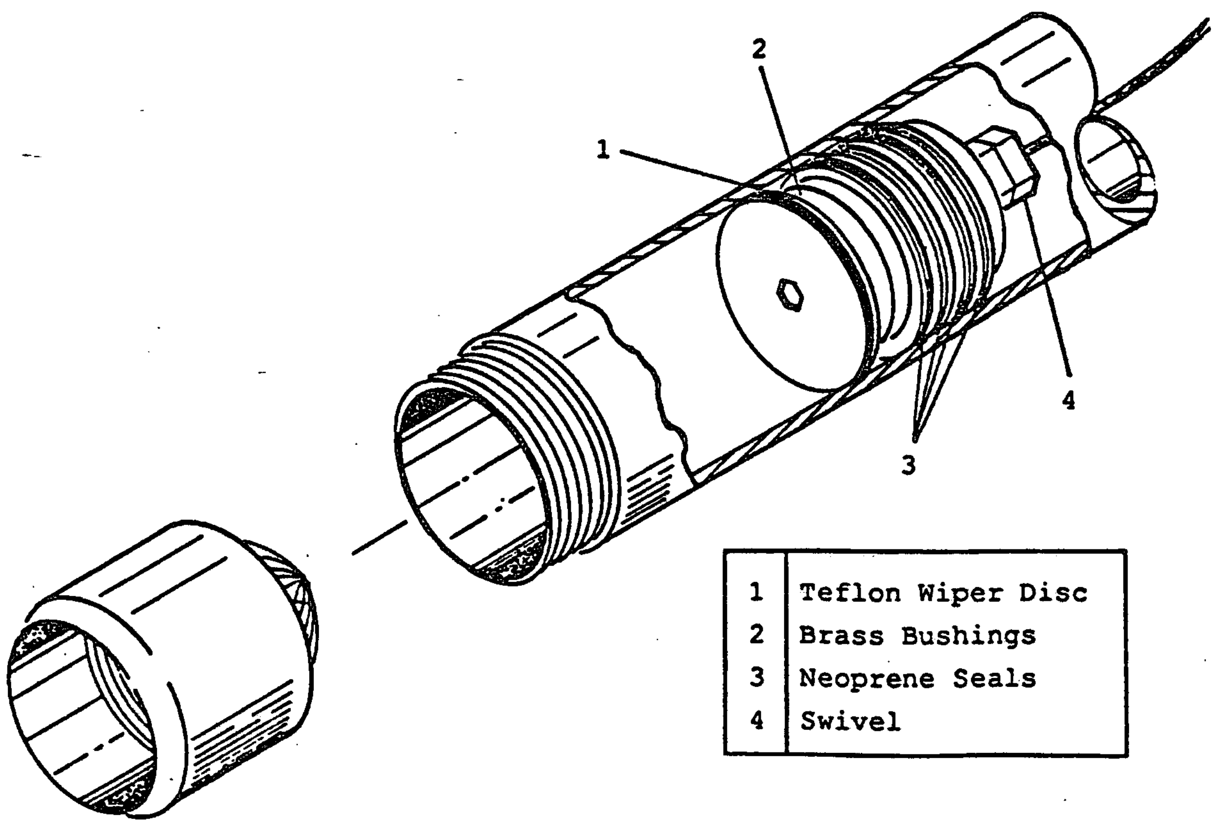

Figure 9. Modified Wireline Piston Design

entering the top of the sample tube when the sampler is lowered below the water table. Waterloo's sampler does not contain the ball valve feature, therefore; any trapped air, water or soil must be vented through the small clearance around the wireline through the drive cap. Since internal pressure above the piston can retard driving the sampler, the ball valve feature was included in the redesign.

The procedures for collecting samples with the modified CME piston sampler include the following:

- The borehole is advanced to the desired sample depth with a clam-shell equipped hollow-stem auger bit in the closed position. The top auger is uncoupled from the rig and left open.

- The modified CME piston sampler is prepared for sampling by positioning the piston at the bottom of the core barrel at a height where a standard core catcher basket and cutting shoe fit snugly against the bottom of the piston when tightened. The eight Allen-head screws are adjusted so an appropriate compression seal can be made with the four neoprene washers. The cutting shoe and core catcher basket are then placed on the sample tube.

- The assembled sampler is lowered inside the auger with attached drill rods until it has made contact with the inner-face of the closed clam-shell. As the sampler is lowered, the wireline attached to the internal piston must be kept slack so the piston will not be pulled upward from its starting position.

- The augers must then be lifted vertically with a separate wireline about 10 inches (25 cm) to open the clam-shell doors, allowing the sampler to settle on the top of the soil to be sampled. An auger holding fork must be inserted and tightened by clockwise rotation so that when the wireline holding the auger column is released, the clam-shell will not be broken from its hinges by the auger string moving back down hole.

- The slack wireline, attached to the internal piston, must then be pulled taut, rigidly fixed to some part of the rig or otherwise held stationary and marked at a fixed reference point.

- The sample tool is then driven to the desired sample depth with a hydraulically operated reciprocating percussion hammer striking an anvil attached to the top of the drill rods. The normal length of core collected in this matter is about 36 inches (100 cm). Extrusion of longer cores is extremely difficult due to friction of the core against the internal wall of the sample tube.

- The sample tool must be carefully detached from soil below the cutting shoe so the core will not be pulled from the sampler during retrieval. This is done by simply rotating the sampler about 180 degrees then slowly lifting it about 4 inches (10 cm). The piston is then slowly pulled to the top of the sample tube, positioning it for easy disassembly at the surface. Positioning of the piston for disassembly after the desired sample volume has been collected is best made while the cutting shoe is still below the groundwater-soil interface. This procedure prevents sample aeration that could occur if the piston is pulled to the top of the sampler in free air. During upward movement of the piston, any water or air trapped above the piston is vented out the top of the sample tube drive cap through the ball valve. The sample tube is then retrieved by slowly hoisting it from the borehole with a wireline attached to the drill rods. Slow retrieval reduces the tendency to suck the sample out of the sampler as it is pulled upward.

- The sampler is quickly disassembled by removing the drive cap and pulling the piston about 4 inches (10 cm) to free it from the top of the sample tube. The sample tube is then placed horizontally in a hydraulic core extruding device. The cutting shoe is loosened so it can be hand turned but temporarily left in place to minimize sample aeration.

CORE COLLECTION INSIDE AN ASEPTIC GLOVE BOX

Introduction

During most geochemical and microbiological core sampling, it is desirable to collect extruded cores in an aseptic and oxygen free environment. This can be accomplished by inserting the end of the sample tube inside a special constucted portable 3/8 inch (1.0 cm) thick plexiglass glove box with dimensions of 2x3x4 feet (60x90x120 cm) for field sampling (Figure 10). This prototype box is equipped with a special self-closing iris diaphragm for insertion of the sample tube. In approximately 30 minutes prior to sampling, the blove box can be prepared for sample collection by filling it with the desired number of presterilized sample containers and sterile stainless steel core paring devices and purging it with nitrogen gas to reduce the oxygen level below detectable limits (Figure 11).

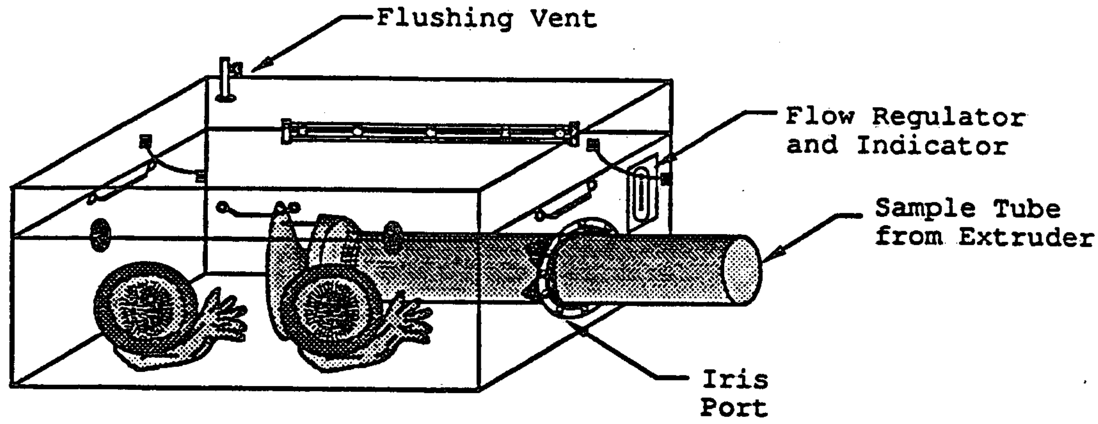

Figure 10. Field Sampling Glove Box

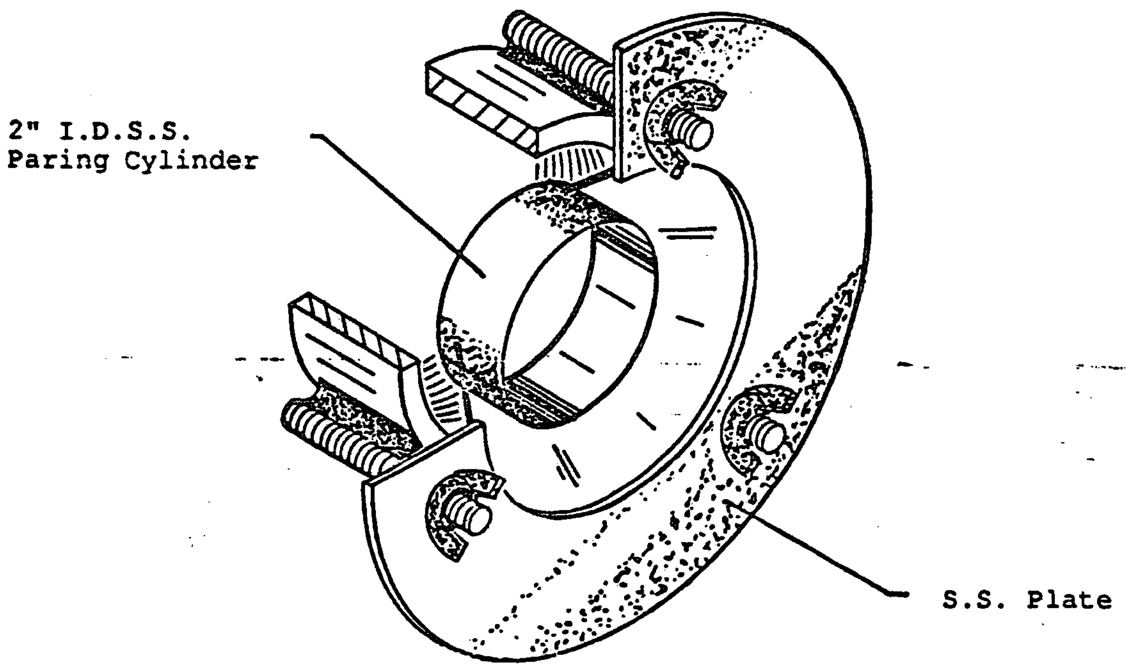

Figure 11. Core Paring Tool

Laboratory Sample Container Preparation

In preparation for a field sampling project, a sufficient number of glass sample containers to collect all the samples planned are sterilized in the laboratory. Sterilization is done by washing the containers and sealable lids, and autoclaving at a temperature of 121°C at 1 atmosphere pressure for 60 minutes. As the containers and lids are removed from the autoclave, they are placed in a laboratory glove box. When filled to capacity, the glove box is sealed and the interior air is flushed from the box by purging with pressurized nitrogen gas for 30 minutes using a flow rate of 90 ft^3/hour (2500 L/hr) at a pressure slightly in excess of atmospheric. This procedure displaces all gases from the sample containers and fills them with nitrogen. After 30 minutes purging, the sample containers are wrapped in aluminum foil, placed on the sample container and the lids are screw hand tight while in the positive pressure nitrogen atmosphere. The glove box is depressurized, leaving a slight positive pressure inside the sample containers. The glove box is opened, containers are removed and packed for transport to the field. The stainless steel paring devices are rinsed in distilled water then wrapped in foil for transport to the field.

Quality assurance test of the field glove box was conducted by measuring a series of 1000 microliter samples of vented gas with a Varian Model 90-P gas chromatograph equipped with a thermal conductivity detector. These test varified that the air-oxygen level inside the box after 30 minutes purging is less than .02 percent on a volume per volume basis.

Core Collection in the Field

In the field, approximately 30 minutes prior to sampling, the portable glove box can be prepared for sampling by filling it with the desired number of presterilized sample containers and sterile stainless steel core paring devices. About 10 minutes prior to placement inside the glove box, the paring devices are rinsed in a 95 percent ethanol bath, placed in a stainless steel pan and ignited to fire-burn dry the excess ethanol. They are then carefully wrapped in sterile aluminum foil and placed in the glove box. The glove box is then closed and purged with pressurized nitrogen gas reducing the oxygen level below detectable limits using the same procedures described for sample container preparation. Once the glove box is purged for 30 minutes, assuring an oxygen free environment, a positive pressure of nitrogen flowing through the box should be maintained during all sampling activities.

After insertion of the sampler into the glove box, the cutting shoe and core catcher basket are removed. A sterilized foil-wrapped paring tool is carefully unwrapped and screwed onto the sample tube, then about 4-inches (10 cm) of soil is extruded through the 2 inch diameter (5 cm) paring tool. This part of the core is carefully broken away exposing an aseptic face. Cores are then routinely collected in sterilized containers and sealed inside the glove box. Paring of the core is necessary to peel away the exterior of the 4-inch (10 cm) diameter core since it becomes disturbed and contaminated forming a slick skin effect by rubbing against the interior of the sample tube during the sample collection process.

Approximately 120 inches (300 cm) of core can be collected during three separate 36 inch (100 cm) sampling events before the glove box must be opened, samples removed, the box thoroughly cleaned, and prepared for repurging. Normally if the samples are to be analyzed for organic compounds or used in microbiological studies, they are exited from the box through the iris diaphram, labeled, placed in an ice chest, and covered with ice for transport to a laboratory.

It is not presently possible to close the clam-shell doors once they have been opened in the subsurface, therefore; if deeper samples are desired, the entire flight of augers must be carefully removed from the borehole without rotation. The annular area of the augers and the clam-shell must be washed with tap water using a high pressure hose for thorough cleaning. The borehole can be backfilled to the surface with cuttings or clean sand and then redrilled to the next desired sampling depth. In some situations researchers may prefer moving the rig a few feet and drilling a new hole. This process is slower than conventional sampling with a pilot assembly, however; it is necessary to remove the augers to clean all heave material from the interior of the augers, properly close the clam-shell doors and backfill the borehole so vertical pressure will hold the clam-shell closed until the next sampling depth is reached. Admittedly, the process is slow but samples of high integrity in heaving material are consistently obtainable.

SUMMARY

Field sampling techniques described in this paper combine a series of innovative drilling and soil coring tools, the basic designs of which were initially developed by others. Normally these tools were used for other borehole construction purposes or under different operating procedures.

Designs of two different soil sampling tools were integrated to combine the most desirable features of each device to enhance sample collection and recovery capabilities. The improved piston design and use of the combination of tools in the sequences described allow researchers to consistently collect samples of the highest in situ integrity without introduction of foreign substances or fluids into the borehole. Greater than 90 percent sample recovery in heaving sands has been consistently demonstrated. Even though the piston sampler techniques can be used in any unconsolidated material with the exception of gravels containing cobbles larger than 1.5-2.0 inches (3.8-5.0 cm) in diameter, in the

interest of time and energy conservation, it is recommended that traditional sampling methods be used until heaving conditions are encountered.

Borehole construction with a clam-shell capped auger head is recommended for drilling in all situations where unconsolidated materials are penetrated and heaving sands are anticipated at the targeted depth. The 8.25 inch (21 cm) I.D. augers fitted with a clam-shell are preferred for use in monitoring well construction because the working space inside the auger and a completed borehole diameter of 12.5 inches (32 cm) allows better construction of the gravel pack and bentonite seal than smaller diameter augers, particularly if installation of casings larger than 2 inch (5 cm) O.D. are planned. However, the 4.25 inch (10 cm) I.D. augers with the auger head fitted with a clam-shell is preferred for both traditional and piston sampling. Heaving between the interior of the cutting head and exterior of the sample tube is very minimal as a result of the small clearance remaining when standard 4.0 inch (10 cm) O.D. sample tubes are used. Even though sampling with the clam-shell capped auger head functions extremely well in heaving sands, it is admittedly a slow and time consuming process because the augers must be pulled from the borehole and the clam-shell closed for each sampling interval. However, at present no other alternative for sampling heaving material exists except where foreign substances are introduced to hydrostatically control heaving. In any case, the driller would want to be assured the annular area of the augers was free of heave material, clean and the clam-shell properly closed at the beginning of each sampling interval. This can only be verified by starting with such conditions at the surface.

A special plexiglass glove box, similar to those normally used in aseptic laboratory studies, was constructed and equipped with a positive pressure nitrogen gas purge system for field use. A transparent box is needed for use in the field so the soil extruding process can be easily observed by the hydraulic systems operator. The integrity of samples are maintained during transfer from the sample tube to storage containers. The necessity of collecting and preserving unaltered samples in the field for research purposes motivated the design and development of this innovative tool.

DISCLAIMER

The design, modifications, fabrication and testing of the combination special tools for hollow-stem auger drilling and sampling described in this article were developed by the United States Environmental Protection Agency in cooperation with the Traverse Group Incorporated, Traverse City, Michigan. The report has not been subjected to Agency review and therefore does not necessarily reflect the views of the Agency and no official endorsement should be inferred. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGEMENTS

The redesign and actual machine construction of the component parts of the wireline internal piston was conducted by Mr. Mike Ettenoffer, Mechanical Engineer with the Traverse Group Incorporated, Traverse City, Michigan, during their 1987 field studies with the authors. Mike Ettenoffer maintained close contact and was continuously advised by the prototype designer, Mike Zapico, University of Waterloo, Ontario, Canada, during the complete modification of the piston for use in the CME thin walled sampler.

Montie Fraser, Engineering Technician of EPA's RSKERL was instrumental in field testing and developing techniques for the most efficient use of the modified piston sampler described in this article. Montie should also be commended for his innovative ideas used in his actual shop fabrication and testing of both the portable plexiglass glove box and prototype stainless steel paring device.

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